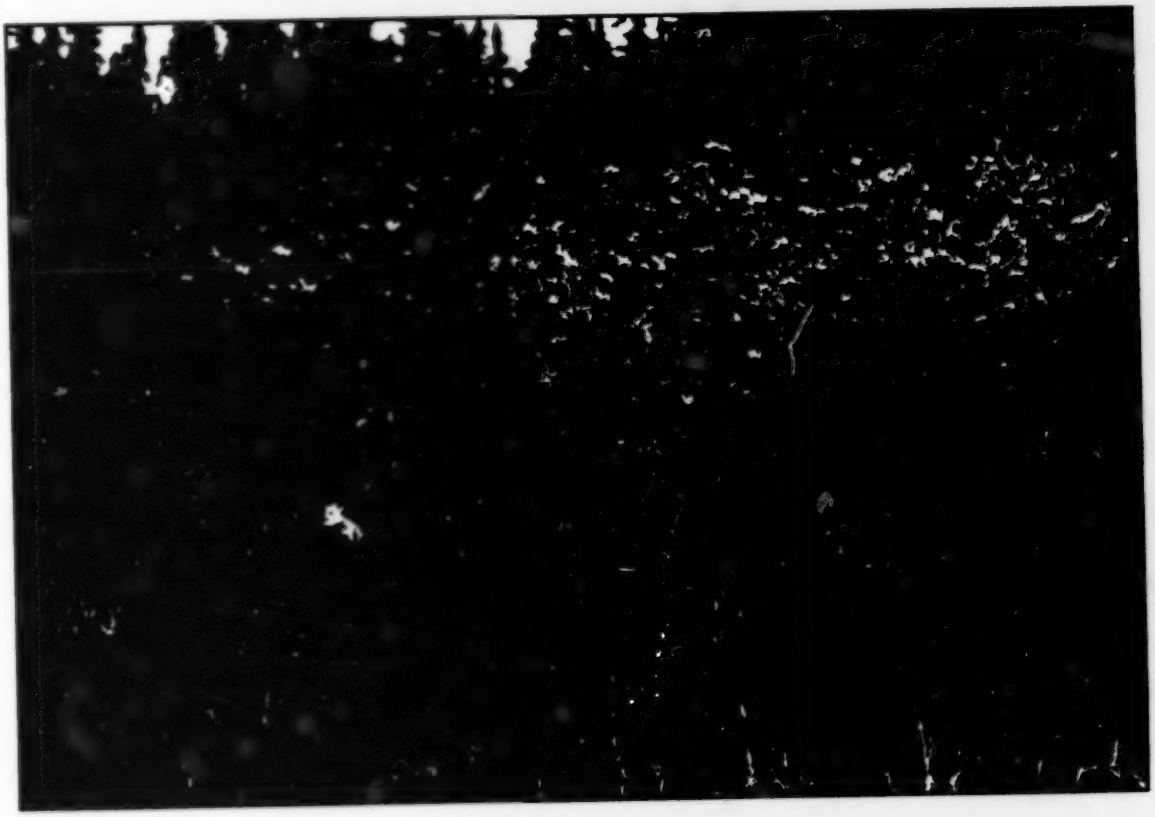
Environment Canada / Environnement Canada
Canadian Forestry Service / Service canadien des forêts

Environment Canada / Environnement Canada
CC16C91K DEST PVM EXCH COPY 03
SD 391 C365
VOL ISS 252
NORTHERN FOREST RESEARCH CENTRE. IN
FORMATION REPORT NOR-X

Jack pine regeneration following postcut burning and seeding in southeastern Manitoba

Z. Chrosciewicz

Information Report NOR-X-252
Northern Forest Research Centre



JACK PINE REGENERATION FOLLOWING POSTCUT BURNING AND SEEDING IN SOUTHEASTERN MANITOBA

Z. CHROSCIEWICZ

INFORMATION REPORT NOR-X-252

NORTHERN FOREST RESEARCH CENTRE
CANADIAN FORESTRY SERVICE
ENVIRONMENT CANADA
1983

•Minister of Supply and Services Canada 1983
Catalogue No. Fo46-12/252E
ISBN 0-662-12864
ISSN 0704-7673

This publication is available at no charge from:

Northern Forest Research Centre
Canadian Forestry Service
Environment Canada
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

Chrosciewicz, Z. 1983. Jack pine regeneration following postcut burning and seeding in southeastern Manitoba. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alberta. Inf. Rep. NOR-X-252.

ABSTRACT

Seventeen experimental burns on various sandy clear-cut sites in southeastern Manitoba were broadcast seeded with jack pine (*Pinus banksiana* Lamb.) at a rate of 1.24 kg/ha to determine the specific treatment combinations that would produce acceptable regeneration. After two growing seasons, the results were predominantly unsatisfactory, and the burns were reseeded at a rate of 0.62 kg/ha. Regeneration of jack pine after seven more growing seasons was a complete failure on the dry and fresh upland sites but was consistently more than adequate on the moist lowland site. The critical deficiencies of soil moisture on the dry and fresh sites and the presence of a high water table within the soil profile on the moist site are believed to be responsible for the mixed results.

RESUME

Dix-sept brûlis expérimentaux sur divers terrains sableux de coupe rase du sud-est du Manitoba ont été ensemencés à la volée en pin gris (*Pinus banksiana* Lamb.) au taux de 1.24 kg/ha afin de déterminer les combinaisons de traitements qui produiraient une régénération acceptable. Après deux saisons de croissance, comme les résultats étaient en majeure partie insatisfaisants, les brûlis ont été réensemencés au taux de 0.62 kg/ha. La régénération après sept autres années de croissance était un échec complet sur les terrains élevés secs et frais, mais était uniformément plus que convenable sur le terrain humide de basse plaine. On pense qu'une insuffisance critique de la teneur en eau des terrains secs et frais et la présence d'une nappe phréatique peu profonde à l'emplacement humide seraient à l'origine des différents résultats obtenus.

CONTENTS

	Page
INTRODUCTION	1
THE CLEAR-CUT SITES	1
METHODS	2
Burning	2
Seeding	2
Sampling	2
RESULTS	3
Fuel Consumption and Seedbeds	3
Jack Pine Regeneration	3
Regeneration of Other Tree Species	4
Recovery of Minor Vegetation	7
DISCUSSION	7
ACKNOWLEDGMENTS	8
REFERENCES	8

TABLES

1.	Jack pine regeneration on seeded postcut burns and undisturbed clear-cut controls, moist site	5
2.	Distribution of rainfall by critical spring and summer months	6

INTRODUCTION

Successful jack pine (*Pinus banksiana* Lamb.)[1] regeneration is rare after harvest cutting and, unless supplementary treatments are undertaken, the areas usually revert to grass, shrubs, and hardwoods (Cayford *et al.* 1967). Field studies in Ontario (Chrosciewicz 1959, 1967, 1968, 1970, 1974) and Minnesota (Ahlgren 1970) have shown that jack pine can be effectively regenerated by the postcut use of burning either in the presence of seed trees or followed by direct seeding. Since 1964 several burns in different combinations with mechanical scarification, seed-tree systems, direct seeding, and planting have been tried under the climate and soil conditions of southeastern Manitoba, but the overall results have been highly variable and mostly discouraging (Cayford 1966; Sims 1976).

Between 1968 and 1972, additional burning and seeding operations were tested over an extended range of weather and site conditions to ascertain which treatments would be more consistently successful in producing acceptable jack pine regeneration. The treatments were carried out at latitudes 49°37'N to 49°39'N and longitudes 96°01'W to 96°04'W on dry to moist sites about 73 km by road east-southeast of Winnipeg, Manitoba. Results of the physical aspects of burning are presented elsewhere (Chrosciewicz 1978a). This report evaluates the treatments in terms of jack pine regeneration and associated vegetation.

THE CLEAR-CUT SITES

The burning and seeding operations were conducted on three flat, clear-cut jack pine sites: two on an upland and one on a lowland. The mineral soil materials were deep, predominantly fine sands on all three sites. Their combined silt-plus-clay contents varied between 8-10% at the mineral surface and 3-4% at about 0.5 m below the surface. The midsummer depths to groundwater averaged more than 2.4 m, 1.8 m, and 0.9 m, and the soil moisture regimes (Hills 1955) were 1, 2, and 4, respectively, for the individual sites. Generally, the three sites matched the Mueller-Dombois (1964) habitat descriptions as "oligotrophic (nutritionally poor), dry, fresh, and moist types" (Chrosciewicz 1978a).

The original stands were 70-80 years old, with basal areas of 18-34 m^2/ha. They were pure jack pine on the dry and fresh upland sites and mostly jack pine with a black spruce (*Picea mariana* (Mill.) BSP.) understory on the moist lowland site. The timber was clear-cut in the spring of 1968, and by the start of burning later that year the residual slash averaged 0.3-0.5 m in depth and had an intermittent ground cover of about 60%. The duff consisted mostly of partially decomposed feather moss and litter materials ranging in depth from 1 to 8 cm on the dry and fresh upland sites and from 2 to 22 cm on the moist lowland site. Some mineral soil was exposed during logging operations, but about 88 to nearly 100% of the original duff cover remained undisturbed (Chrosciewicz 1978a).

Among the plant species found growing on all three clear-cut sites were Schreber's moss (*Pleurozium schreberi* (Brid.) Mitt.), strawberry (*Fragaria virginiana* Duchesne), low sweet blueberry (*Vaccinium angustifolium* Ait.), and rose (*Rosa acicularis* Lindl.). Common bearberry (*Arctostaphylos uva-ursi* (L.) Spreng.), mountain rice (*Oryzopsis pungens* (Torr.) Hitchc.), choke-cherry (*Prunus virginiana* L.), and serviceberry (*Amelanchier alnifolia* Nutt.) were

---

[1]Species nomenclature follows Scoggan (1957) for vascular plants, Crum *et al.* (1973) for mosses, and Hale and Culberson (1970) for lichens.

present in large numbers on the dry and fresh sites, whereas twinflower (*Linnaea borealis* L. var. *americana* (Forbes) Rehd.) and raspberry (*Rubus idaeus* L. var. *strigosus* (Michx.) Maxim.) grew well on the fresh and moist sites. Reindeer moss (*Cladina rangiferina* (L.) Herm.), Canada everlasting (*Antennaria canadensis* Greene), and redroot (*Ceanothus ovatus* Desf.) were found almost exclusively on the dry site, and bunchberry (*Cornus canadensis* L.), sweet coltsfoot (*Petasites palmatus* (Ait.) Gray), blue-joint (*Calamagrostis canadensis* (Michx.) Nutt.), bracken (*Pteridium aquilinum* (L.) Kuhn var. *latiusculum* (Desv.) Underw.), Labrador tea (*Ledum groenlandicum* Oeder), aspen (*Populus tremuloides* Michx.), and alders (*Alnus crispa* (Ait.) Pursh and *A. rugosa* (Du Roi) Spreng. var. *americana* (Regel) Fern.) grew abundantly on the moist site. The vegetation averaged 0.3-0.6 m in height, with some shrubs reaching 1.8 m. Total moss cover was 20% on the dry and fresh upland sites and 90% on the moist lowland site. The herbs, grasses, and shrubs provided a combined cover of about 80% on all three sites (Chrosciewicz 1978a).

METHODS

Burning

Seventeen 0.16-ha plots, each enclosed by a 6-m wide bulldozed fire guard, were burned over in 1968 and 1969: seven on the dry site, five on the fresh site, and five on the moist site. The Duff Moisture Code (DMC) ratings associated with the individual burns ranged from 13 to 44 so that different degrees of burn were obtained in terms of duff consumption. The relatively high Fine Fuel Moisture Code (FFMC) ratings of 86-92 on the days of burning ensured that the fine, dead, aerial and surface fuels were sufficiently dry to sustain ignition. The burns were also characterized by Buildup Index (BUI) ratings of 22-63, Initial Spread Index (ISI) ratings of 4-15, and Fire Weather Index (FWI) ratings of 11-26 (Chrosciewicz 1978a). All these rating values were determined from direct measurements of local weather with the aid of standard tables (Environment Canada 1978; Van Wagner 1974).

Seeding

The 17 burned plots were uniformly seeded to jack pine on June 2, 1970, at a rate of 1.24 kg of seed/ha. After two growing seasons, jack pine regeneration was largely inadequate and reseeding was required. This was done on April 13, 1972, with all 17 burned plots seeded again to jack pine at the rate of 0.62 kg of seed/ha. The seeds were of local origin and had a germinating capacity of 88-89%. A cyclone seeder was used in both operations.

Sampling

Wherever possible, the 0.16-ha burned and seeded plots were grouped by site in a grid formation, with two 0.04-ha undisturbed clear-cut controls per site representing the pretreatment conditions. The burned and seeded plots and the undisturbed controls were 40 x 40 m and 20 x 20 m, respectively. Uniformly spaced transects, 10 per burned and seeded plot and five per undisturbed control, formed the original base of sampling for both the fuels and the seedbed conditions before and after burning. The transects consisted of single rows of 4-m^2 sample quadrats, 20 per transect on the burned and seeded plots, and 10 per transect on the undisturbed controls. This arrangement resulted in 200 sample quadrats per burned and seeded plot and 50 sample quadrats per undisturbed control, uniformly giving 50% of areal sampling.

Where applicable, the seedbed conditions were assessed both after logging and after burning. This assessment included mapping to scale the exposure of mineral soil and the extent of burn on all 4-m^2 sample quadrats, and

measurements of the duff depths before and after burning at randomly spaced steel observation pins along middle lines of the transects. The number of observation pins was always the same as the number of sample quadrats.

Regeneration was surveyed in the midsummer of 1978 after all height growth had ceased for the year. This was done using four uniformly spaced transects per burned and seeded plot and two per undisturbed control. The resulting 80 sample quadrats per burned and seeded plot and 20 sample quadrats per control provided for 20% of areal sampling. The data from the two controls on any given site were combined.

Individual jack pine, black spruce, aspen, and tamarack (*Larix laricina* (Du Roi) K. Koch) were counted on all 4-m^2 quadrats sampled. This count was supplemented with height measurements of dominant stems, one per species, on each stocked quadrat. Ages of dominant jack pine were determined from annual rings of a few samples taken between the transects. Changes in species composition, ground cover, and height of minor vegetation were also noted for each site. In cases where the forest regeneration completely failed, a general inspection of the affected plots was carried out in place of the regular regeneration survey.

To characterize the growing seasons immediately following the seeding and reseeding operations, monthly rainfall totals for June-September, 1970, and April-September, 1972, were compared with the corresponding monthly rainfall normals. The data used in this comparison were collected at the Steinbach, Manitoba, weather station, about 45-48 km west-southwest of the experimental sites.

RESULTS

Fuel Consumption and Seedbeds

In this series of burns (Chrosciewicz 1978a), as in other experiments (Chrosciewicz 1959, 1967, 1968, 1970, 1974, 1978b, c, d, 1980, 1983), the fires consumed much of the unwanted logging slash, the aerial parts of vegetation, surface litter, and underlying duff in quantities that on the average were directly related to the drought conditions or the fuel moisture code ratings under which the materials were burned. The organic materials that remained after the fires included surface-charred stumps and other large pieces of wood, partially burned duff with some unburned plant roots, and occasional patches of unburned litter and duff over which the plants became scorched.

The total area burned ranged between plots from 69.1 to 97.4% on the dry site, from 64.3 to 85.0% on the fresh site, and from 50.6 to 81.9% on the moist site. Similarly, the postburn exposure of mineral soil ranged between plots from 19.7 to 64.3% on the dry site, from 7.9 to 37.8% on the fresh site, and from 3.4 to 11.3% on the moist site. It is worthwhile to note that the values in both these parameters generally decreased with the increasing soil moisture regime. The mean postburn duff depth, however, increased with the increasing soil moisture regime, varying between plots from 0.3 to 1.8 cm on the dry site, from 1.2 to 1.9 cm on the fresh site, and from 6.5 to 10.3 cm on the moist site.

No mineral soil was exposed on the undisturbed controls, and mean duff depths were 2.6 cm on the dry site, 2.8 cm on the fresh site, and 10.0 cm on the moist site.

Jack Pine Regeneration

Whether the plots were treated or left undisturbed, jack pine completely failed to regenerate on the dry and fresh upland sites. The initial postburn seeding

in 1970 was ineffective and results were equally poor after reseeding in 1972. Regardless of the degree of burn and the amount of mineral soil exposure, all burned and seeded plots, as well as the undisturbed clear-cut controls, were totally devoid of pine regeneration on both these sites.

In contrast, the burning and seeding treatments were highly successful on the moist lowland site. Benefiting from the fire-improved seedbeds (Table 1), the 1978 jack pine stocking on 4-m^2 quadrats was 60% on one treated plot and 76-94% on the remaining four treated plots. The number of living pine associated with this stocking (10 873-29 807/ha) was more than adequate for future stand development, and the dominant seedlings ranged in mean height from 2.03 (± 0.85) to 2.68 (± 0.60) m. Ring counts indicated that many of the dominant pine seedlings on the treated plots originated from the initial postburn seeding in 1970 and that only some came up after the reseeding in 1972. The combined pine regeneration on the undisturbed clear-cut moist-site controls (Table 1) was generally poor, with only 8% stocking, 247 seedlings/ha, and 1.92 (±1.56) m mean height of dominants. The dominant seedlings on the controls were about 2 years older than those on the treated plots.

Field observations showed that jack pine on the moist lowland site regenerated just as well on the partially burned duff as on the exposed mineral soil and that most of the seedlings were found growing on these two types of seedbeds. Undisturbed duff, both in residual patches on the treated plots and forming the predominant ground cover on the controls, was an unfavorable seedbed medium; here, a few occasional pine seedlings were found growing but only on some of the more favorable microsites such as small depressions, places next to the stumps, and places with decayed wood at the surface.

The weather that immediately followed the seeding and reseeding operations was much drier than normal for nearly three months (June-August) in 1970 and for over three months (April-July) in 1972 (Table 2). Soil moisture and jack pine regeneration on the dry and fresh upland sites were adversely affected by these rainfall deficits. On the moist lowland site, however, the pine regenerated well under the same weather patterns, mainly because of a more favorable position of groundwater. The observed subsurface water table on this site fluctuated at depths from 0.2 m in spring to 0.9 m in midsummer, and much of the soil moisture was supplied from this source through the upward extension of the capillary fringe in addition to the amounts of rainfall received. The capillary fringe seldom exceeded 0.3 m in sandy soils (Keen 1931), but this was apparently sufficient to keep the seedbeds adequately moist during the early parts of the growing seasons when most of the pine probably germinated. By the time the water table and the associated capillary fringe on this site receded, the seedlings were firmly established, benefiting later from the moister-than-normal weather in both September of 1970 and August-September of 1972 (Table 2).

Regeneration of Other Tree Species

There was also no regeneration of other commercial tree species on the dry and fresh upland sites. The results on the treated plots were no better than the results on the undisturbed clear-cut controls.

The situation was entirely different, however, on the moist lowland site, where after pine, aspen root suckers were the most abundant, with 1202-2378 stems/ha on the treated plots and 741 stems/ha on the undisturbed controls. Black spruce ranked second, with 278-1637 seedlings/ha on the treated plots and 494 seedlings/ha on the controls. Tamarack, with 31-803 seedlings/ha on the treated plots and 124 seedlings/ha on the controls, was the least abundant and only occurred sporadically. The

Table 1. Jack pine regeneration on seeded postcut burns[a] and undisturbed clear-cut controls, moist site[b]

Plot No.	Seedbeds			Jack pine regeneration				
	Total area burned (%)	Exposed mineral soil (%)	Mean duff depth (cm)	4-m^2 quadrats sampled (n)	4-m^2 quadrats stocked (%)	Total living seedlings (n/ha)	Dominant seedling heights measured (n)	Mean dominant seedling height[c] (m)
31	50.6	9.1	10.3	80	60	13 838	48	2.68 (± 0.60)
29	59.9	3.4	8.2	80	76	12 602	61	2.03 (± 0.85)
28	70.5	3.8	8.4	80	85	17 133	68	2.18 (± 0.83)
30	71.0	5.8	6.5	80	79	10 873	63	2.11 (± 0.68)
32	81.9	11.3	7.8	80	94	29 807	75	2.38 (± 0.75)
Controls	0	0	10.0	40	8	247	3	1.92 (± 1.56)

[a] Clear-cut in spring of 1968, burned over in summer of 1969, broadcast seeded to jack pine in spring of 1970 (1.24 kg of seed/ha, viability 88%), reseeded to jack pine in spring of 1972, (0.62 kg of seed/ha, viability 89%), regeneration sampled in summer of 1978.

[b] Flat lowland, thick duff over fine sand, midsummer depth to water table 0.9 m, soil moisture regime 4.

[c] Standard deviations in parentheses.

Table 2. Distribution of rainfall by critical spring and summer months[a]

Month	Steinbach weather station					
	1970		1972		Normals	
	Total rainfall (mm)	Days with rain (n)	Total rainfall (mm)	Days with rain (n)	Total rainfall (mm)	Days with rain (n)
April	Not applicable		3.8[b]	3[b]	36.6	8
May	Not applicable		31.5	2	70.6	11
June	50.3[c]	12[c]	73.2	7	84.6	11
July	70.6	12	55.1	8	77.5	12
August	27.4	7	94.0	5	73.7	10
September	83.3	13	63.8	8	55.4	9

a All values based on measurable rains (>0.1 mm) within 24-h days (Canada Department of Transport 1970; Environment Canada 1972, 1975).
b Postcut burns reseeded to jack pine on April 13, 1972.
c Postcut burns seeded to jack pine on June 2, 1970.

dominants on the treated plots ranged in mean height from 1.06 (± 0.54) to 2.88 (± 1.61) m for aspen, from 0.38 (± 0.20) to 0.75 (± 0.63) m for black spruce, and from 0.62 (± 0.23) to 1.38 (± 1.51) m for tamarack. Although the dominants on the moist-site controls were about 2 years older than those on the treated plots, their mean heights of 2.35 (± 0.97) m for aspen, 0.51 (± 0.12) m for black spruce, and 0.91 (± 0.07) m for tamarack were roughly comparable to those on the treated plots.

As with jack pine, regeneration of aspen, black spruce, and tamarack on the moist site benefited from the positive effects of groundwater within the soil profile. Burning had a consistently stimulating effect on aspen root suckering, but the numerical responses of black spruce and tamarack regeneration to burning were variable, probably because of differences in access to local seed sources.

Recovery of Minor Vegetation

The 1978 minor vegetation on the treated plots included some of the original species that were there before burning and a few additional ones that gradually seeded-in from adjoining areas. Strawberry, low sweet blueberry, wild lily-of-the-valley (*Maianthemum canadense* Desf.), aster (*Aster ciliolatus* Lindl.), sedge (*Carex* spp.), grass (*Graminae* spp.), and rose were growing in quantity on all three sites. Common bearberry, choke-cherry, and serviceberry were the other main species on the dry and fresh upland sites, whereas bunchberry, sweet coltsfoot, bracken, Labrador tea, shrubby cinquefoil (*Potentilla fruticosa* L.), red osier (*Cornus stolonifera* Michx.), willow (*Salix bebbiana* Sarg.), and alders grew well on the moist lowland site. Not including postburn regeneration of the commercial tree species, the remaining vegetation still averaged 0.3-0.6 m in height on the various sites, with some of the shrubs reaching 0.8 m on the dry site, 1.5 m on the fresh site, and 3.6 m on the moist site. Mosses almost completely disappeared, and the total ground cover provided by herbs, sedges, grasses, and shrubs varied between sites from about 90 to 95%.

The plant competition was generally much more severe on the moist lowland site than on either the dry or the fresh upland site, but this had no detrimental effect on regeneration of commercial tree species, including pine.

DISCUSSION

Seedbeds consisting of exposed mineral soil are generally considered favorable for germination and survival of jack pine (Cayford *et al.* 1967), but a complete, large-scale removal of the organic forest floor materials either by burning or by mechanical means is seldom if ever required to secure the desired results (Chrosciewicz 1978d, 1980). In fact, the best fire-produced seedbeds on moderately dry to moderately moist upland sites are where exposed mineral soil and thin residual duff alternate and have uniform areal distribution. Deeper duff and peat materials on moist to very moist lowland sites become favorable seedbeds almost as soon as the fire burns off the loose surface feather moss and litter. Various means of selecting the proper conditions for burning the desired amounts of duff or peat have been reported elsewhere (Chrosciewicz 1959, 1967, 1968, 1974, 1976, 1978a, b, c).

According to these standards, all the postburn seedbed conditions in the experiment described here should have been favorable for jack pine regeneration. This was not the case, however, on the dry and fresh upland sites where the pine completely failed to regenerate regardless of whether the seedbeds were improved. In the absence of groundwater near the soil surface, the fine sands on both these sites were too dry for successful pine regeneration, particularly

when the amounts of rainfall received were less than normal.

Jack pine regeneration might have been adequate if there had been substantially more silt and clay intermixed with the sand on the dry and fresh upland sites, as this would have increased both the water-holding capacity and the nutrient status of the soil profile. The enhanced silt-plus-clay content is known to improve the quality of the otherwise sandy soil and this, in turn, has a positive effect on pine regeneration (Chrosciewicz 1970). Similarly, had there been substantially more well-distributed rainfall following the seeding or reseeding operations on these sites, jack pine regeneration might also have been adequate even on the existing seedbeds with the otherwise dry sand and residual duff. Under sustained wet-weather conditions, the pine is known to regenerate well on all kinds of seedbeds, including the normally unfavorable ones with thick, loose, undisturbed feather moss and litter materials (Chrosciewicz 1983).

The successful jack pine regeneration on the equally sandy but moist lowland site was attributable to the presence of a high water table that supplied the soil profile with much of its moisture in addition to the amounts received as rainfall. Under these improved soil-moisture conditions, both the partially burned duff and the exposed mineral soil were favorable seedbeds while the undisturbed duff was not. By the time of survey, the predominantly pine stands were firmly established and showing no ill effects from competing vegetation.

Because neither pine germination nor pine mortality was monitored following the seeding and reseeding operations, no precise cause and effect relationships with the changing immediate environment could be defined. Moreover, the specific site and treatment combinations lacked adequate replications in both time and space, and consequently the results did not lend themselves to statistical analysis. Nevertheless, the experiment clearly demonstrated the advantages and limitations of the burning and seeding treatments on the sandy pine sites studied in southeastern Manitoba. It is hoped that this information will help the forest manager in his decisions on when and where to use similar treatments for the desired regeneration of clear-cut sites back to pine.

ACKNOWLEDGMENTS

The Manitoba Department of Natural Resources provided men, materials, and equipment during the application of treatments. H.C. Tirschmann, then Regional Supervisor, directed burning operations; L.G. Yarn, then Regional Forester, and W. Trowsdale, then Resource Technician, oversaw subsequent seeding and reseeding of pine.

REFERENCES

Ahlgren, C.E. 1970. Some effects of prescribed burning on jack pine reproduction in northeastern Minnesota. Agric. Exp. Stn., Univ. Minnesota, St. Paul, Minn. Misc. Rep. 94.

Canada Department of Transport. 1970. Monthly record, meteorological observations in Canada. June-September 1970. Meteorol. Branch, Toronto, Ont.

Cayford, J.H. 1966. Some aspects of jack pine regeneration on prescribed burned areas. Can. Dep. For. Rural Dev., For. Branch. Bi-Mon. Res. Notes 22:7.

Cayford, J.H.; Chrosciewicz, Z.; Sims, H.P. 1967. A review of silvicultural research in jack pine. Can. Dep. For. Rural Dev., For. Branch, Ottawa, Ont. Publ. 1173.

Chrosciewicz, Z. 1959. Controlled burning experiments on jack pine sites. Can. Dep. North. Aff. Natl. Resour., For. Branch, For. Res. Div. Ottawa, Ont. Tech. Note 72.

Chrosciewicz, Z. 1967. Experimental burning for humus disposal on clear-cut jack pine sites in central Ontario. Can. Dep. For. Rural Dev., For. Branch, Ottawa, Ont. Publ. 1181.

Chrosciewicz, Z. 1968. Drought conditions for burning raw humus on clear-cut jack pine sites in central Ontario. For. Chron. 44:30-31.

Chrosciewicz, Z. 1970. Regeneration of jack pine by burning and seeding treatments on clear-cut sites in central Ontario. Can. Dep. Fish. For., Can. For. Serv., For. Res. Lab., Ont. Reg. Sault Ste. Marie, Ont. Inf. Rep. 0-X-138.

Chrosciewicz, Z. 1974. Evaluation of fire-produced seedbeds for jack pine regeneration in central Ontario. Can. J. For. Res. 4:455-457.

Chrosciewicz, Z. 1976. Burning for black spruce regeneration on a lowland cutover site in southeastern Manitoba. Can. J. For. Res. 6:179-186.

Chrosciewicz, Z. 1978a. Slash and duff reduction by burning on clear-cut jack pine sites in southeastern Manitoba. Fish. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alta. Inf. Rep. NOR-X-199.

Chrosciewicz, Z. 1978b. Slash and duff reduction by burning on clear-cut jack pine sites in central Saskatchewan. Fish. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alta. Inf. Rep. NOR-X-200.

Chrosciewicz, Z. 1978c. Large-scale operational burns for slash disposal and conifer reproduction in central Saskatchewan. Fish. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alta. Inf. Rep. NOR-X-201.

Chrosciewicz, Z. 1978d. Silvicultural uses of fire in midwestern Canada. Pages 37-46 *in* D.E. Dube, compiler. Fire ecology in resource management. Workshop proceedings. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alta. Inf. Rep. NOR-X-210.

Chrosciewicz, Z. 1980. Some practical methods for securing adequate postcut forest reproduction in Canada. Pages 49-52 *in* M. Murray and R.M. Van Veldhuizen, editors. Forest regeneration at high latitudes. The proceedings of an international workshop. USDA For. Serv., Pac. Northwest For. Range Exp. Stn. Portland, Ore. Gen. Tech. Rep. PNW-107.

Chrosciewicz, Z. 1983. Jack pine regeneration following postcut burning and seeding in central Saskatchewan. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alta. Inf. Rep. NOR-X-253

Crum, H.A.; Steere, W.C.; Anderson, L.E. 1973. A new list of mosses of North America north of Mexico. Bryologist 74:85-130.

Environment Canada. 1972. Monthly record, meteorological observations in Canada. April-September 1972. Atmos. Environ. Downsview, Ont.

Environment Canada. 1975. Canadian normals, precipitation 1941-1970. Atmos. Environ. Downsview, Ont. Vol. 2-SI.

Environment Canada. 1978. Canadian Forest Fire Weather Index tables. Can. For. Serv. Ottawa, Ont. For. Tech. Rep. 25.

Hale, M.E. Jr.; Culberson, W.L. 1970. A fourth checklist of the lichens of the continental United States and Canada. Bryologist 73:499-543.

Hills, G.A. 1955. Field methods for investigating site. Ont. Dep. Lands For., Res. Div. Maple, Ont. Site. Res. Man. 4.

Keen, B.A. 1931. The physical properties of the soil. Longmans, Green and Co., London, England.

Mueller-Dombois, D. 1964. The forest habitat types in southeastern Manitoba and their application to forest management. Can. J. Bot. 42:1417-1444.

Scoggan, H.J. 1957. Flora of Manitoba. Can. Dep. North. Aff. Natl. Resour., Natl. Mus. Can. Ottawa, Ont. Bull. 140.

Sims, H.P. 1976. The effects of prescribed burning on some physical soil properties of jack pine sites in southeastern Manitoba. Can. J. For. Res. 6:58-68.

Van Wagner, C.E. 1974. Structure of the Canadian Forest Fire Weather Index. Can. Dep. Environ., Can. For. Serv. Ottawa, Ont. Publ. 1333.